(19) JAPANESE PATENT OFFICE

PATENT ABSTRACTS OF JAPAN

(11) Publication number: **09120154 A**

(43) Date of publication of application: **06.05.97**

(51) Int. Cl **G03F 1/08**
G02B 5/30
H01L 21/027

(21) Application number: **07277387**

(22) Date of filing: **25.10.95**

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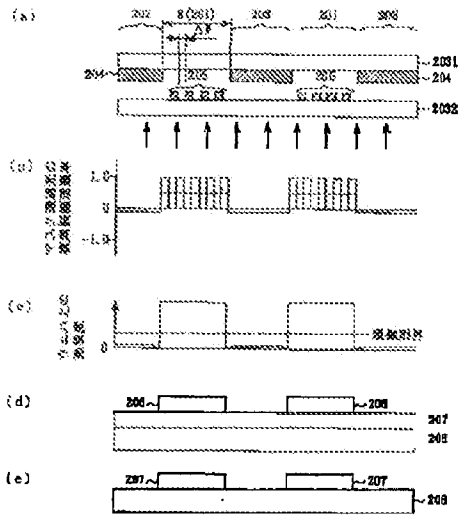
(54) POLARIZING MASK AND ITS PRODUCTION AS WELL AS PATTERN EXPOSURE METHOD AND PATTERN PROJECTION ALIGNER USING THE SAME

(57) Abstract:

PROBLEM TO BE SOLVED: To embody the resolution equiv. to or higher than the resolution of the conventional phase shift method without the formation of such patterns of which the design is infeasible.

SOLUTION: A halftone phase shifter 204 is arranged on the outer or inner side of a fine pattern group which is formed on a mask and has a polarization characteristic. This mask is irradiated with annular band-shaped illumination light in such a manner that the polarization direction is made rotationally symmetrical with respect to the optical axis on the pupil of the projecting optical system of this illumination light, by which the phase shifter is exposed with the transmitted light. The mask is otherwise irradiated with the annular band-shaped illumination light in non-polarization state and the transmitted light is passed through an analyzer which is arranged on the pupil and is rotationally symmetrical in the polarization direction, by which the phase shifter is exposed.



* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]
[Claim 1]A polarization characteristic according to a direction which a pattern on a mask turns to. In parallel or a polarization mask which intersects perpendicularly in general in general a tangential direction of edge of a pattern of a polarization mask which gives the polarization characteristic of pattern dependence given to illumination light which penetrates the above-mentioned pattern, and a polarization direction of light which penetrated the above-mentioned pattern of the above-mentioned illumination light, A polarization mask, wherein it comprises the portion B which shades mostly although a pattern on a mask is penetrated the portion A which penetrates illumination light, and a little, light which penetrates the portion A and the portion B differs in 180 degrees of phases mutually and light intensity of edge of the portion A on an object to be exposed serves as zero.
[Claim 2]an account of the upper -- the polarization mask according to claim 1 whose amplitude transmittance of the portion B which shades mostly is 30% or less effectually to amplitude transmittance of the penetrating above-mentioned portion A.
[Claim 3]an account of the upper -- the polarization mask according to claim 2 whose amplitude transmittance of the portion B which shades mostly is about 22% effectually to amplitude transmittance of the penetrating above-mentioned portion A.
[Claim 4]an account of the upper -- the polarization mask according to claim 1 which limits the portion B which shades mostly near the penetrating above-mentioned portion A, and exists.
[Claim 5]the penetrating above-mentioned portion A and an account of the upper -- the polarization mask according to claim 4 which the portion B which shades mostly was formed on a respectively separate transparent substrate, and has faced mutually on both sides of an air layer.
[Claim 6]an account of the upper -- the polarization mask according to claim 4 which only material in which 180 degrees of phases differ from the portion A among the portions B which shade mostly faces mutually on both sides of the remainder, and the portion A and

an air layer of the portion B, and is formed on a respectively separate transparent substrate.

[Claim 7]the above -- the polarization mask according to claim 5 or 6 which opposed a mask superposition mark mutually on both sides of an air layer, and formed it in a separate transparent substrate.

[Claim 8]the penetrating above-mentioned portion A and an account of the upper -- the polarization mask according to claim 4 in which the portion B which shades mostly is formed on the same field of the same transparent substrate.

[Claim 9]the portion C which shades illumination light thoroughly -- an account of the upper -- the polarization mask according to claim 4 which limits and exists near the portion B which shades mostly.

[Claim 10]A polarization characteristic according to a direction which a pattern on a mask turns to. In parallel or a polarization mask which intersects perpendicularly in general in general a tangential direction of edge of a pattern of a polarization mask which gives the polarization characteristic of pattern dependence made to give illumination light which penetrates the above-mentioned pattern, and a polarization direction of light which penetrated the above-mentioned pattern of the above-mentioned illumination light, A polarization mask, wherein a means to give the above-mentioned polarization characteristic consists of minute slit structure.

[Claim 11]The polarization mask according to claim 10 in which the above-mentioned minute slit structure consists of structure where a thin line of the detailed singular number or plurality is formed along a line of edge of a pattern transparent part.

[Claim 12]The polarization mask according to claim 11 whose thin line of the detailed singular number of the above-mentioned minute slit structure or plurality is conductivity.

[Claim 13]The polarization mask according to claim 12 whose width of an opening of the above-mentioned minute slit is or less about 1 of the exposure wavelength lambda / 2.

[Claim 14]The polarization mask according to claim 11 in which a thin line of the detailed singular number of the above-mentioned minute slit structure or plurality exists in a mask.

[Claim 15]A polarization characteristic according to a direction which a pattern on a mask turns to. In a manufacturing method of parallel or a polarization mask which intersects perpendicularly in general in general a tangential direction of edge of a pattern of a polarization mask which gives the polarization characteristic of pattern dependence made to give illumination light which penetrates the above-mentioned pattern, and a polarization direction of light which penetrated the above-mentioned pattern of the above-mentioned illumination light, A manufacturing method of a polarization mask, wherein a means to give the above-mentioned polarization characteristic is obtained by using a focused ion beam for a transparent membrane on a transparent substrate, vapor-depositing a detailed slot by the singular number or two or more engraving, vapor-depositing a conductive material by a sputtering technique, and leaving only a thin slot of the detailed singular number or plurality by polish.

[Claim 16]A mask or a reticle by which an original picture pattern of a request of light from an illumination light source for exposure was drawn is had and irradiated with desired directivity, In a pattern exposure method which projects the transmitted light of the above-mentioned mask on an object to be exposed through a projection optical system, and exposes an image from the above-mentioned original picture pattern, A pattern exposure method using a polarization mask given in this illumination light that penetrated the above-mentioned pattern for a polarization characteristic according to a direction which a pattern on the above-mentioned mask turns to at either of grant bundle ******** 1 thru/or 15.

[Claim 17]The pattern exposure method according to claim 16, wherein the directivity of the above-mentioned illumination light is way lighting which is zona-orbicularis-illuminated or is shot.

[Claim 18]The pattern exposure method according to claim 16 or 17 in which the polarization condition is the symmetry of revolution in general to a pupil center when the above-mentioned lighting on a pupil of the above-mentioned projection optical system does not have the above-mentioned mask.

[Claim 19]The pattern exposure method according to claim 16 or 17 with which a polarization condition has arranged a polarizing element or a light analysis element which is the symmetry of revolution in general to a pupil center near the pupil of the above-mentioned projection optical system.

[Claim 20]A pattern exposure method given in a paragraph to claim 17 one side passes along a pupil of the above-mentioned projection optical system among primary [**] lights of the diffracted light from the minimum pattern on a mask in which the directivity of the above-mentioned way lighting which is zona-orbicularis-illuminated or is shot was illuminated by this illumination light, and kept another side from passing along a pupil.

[Claim 21]The pattern exposure method according to claim 16 whose above-mentioned illumination light is usually lighting, whose directivity sigma of the is 0.5 or more and in which the polarization condition is the symmetry of revolution in general to a pupil center when the above-mentioned illumination light does not have the above-mentioned mask.

[Claim 22]A pattern projection aligner comprising:

An illumination-light study system made to have and irradiate with the directivity of a request of light emitted from a mask or a reticle by which an original picture pattern of an exposure illumination light source and a request was drawn, and the above-mentioned light source on the above-mentioned mask.

A polarization means which a polarization condition on a pupil of the above-mentioned projection optical system of the above-mentioned illumination light makes serve as the symmetry of revolution in general to a pupil center in a pattern exposure device which consists of a projection optical system which projects the transmitted light of the above-mentioned mask on an object to be exposed when there is no above-mentioned mask.

[Claim 23]The pattern projection aligner possessing a deformation illumination means to

realize way lighting which is zona-orbicularis-illuminated or the above-mentioned illumination-light study system shoots according to claim 22.

[Claim 24]The pattern projection aligner according to claim 22 or 23 with which the above-mentioned polarization means is effectually included in the above-mentioned illumination-light study system.

[Claim 25]The pattern projection aligner according to claim 22 or 23 with which the above-mentioned polarization means is included in the above-mentioned projection optical system.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to the polarization mask used for forming a detailed circuit pattern, the exposure method using this polarization mask, and a projection aligner, and relates to exposure of the pattern of the line width near the limit of the pattern dimension decided to the diffraction limit of the light especially used for exposure.
[0002]
[Description of the Prior Art]The minuteness making of an integrated circuit progresses and the field of the minimum line width which is decided by the diffraction limit of light and which can be exposed is approached. For this reason, various kinds of devices called super resolution art are performed to the mask and the projection aligner in recent years. In the exposure wavelength, when the resolution R of the exposure optical system set the numerical aperture of lambda and a projection optical system to NA, it was decided by $R=k_1$ lambda/NA, and as for k_1, 0.6 to about 0.8 were conventionally considered to be a limit in general.
[0003]Various kinds of devices exceeded this limit, and have attracted attention as a method of also solving the problem of reduction of the focal seismic intensity which moreover becomes increasingly severe in connection with minuteness making to some extent. As the typical art, ** phase shift method (it devises on a mask), ** zona-orbicularis illumination, method illumination (it devises to a projection aligner) of ** diagonal slanting, etc. have been examined.
[0004]** If a method is used, when making it 180 degrees of phases of the transmitted light of a mask pattern shift mutually between the adjacent patterns of a recurrent pattern as shown in drawing 29 (a), (b), and (c), The light intensity between the adjacent patterns of the pattern by which image formation was carried out by the projection optical system turns to 0, and separation between recurrent patterns can be performed very good. However, since this method cannot necessarily change 180 degrees of phases between adjacent patterns when it becomes a two-dimensional pattern as shown in drawing 30 (a), (b), and

(c), the portion which is not resolved beyond the conventional exposure method will generate it. When this designs a pattern, it becomes very big restrictions, and the pattern which cannot be designed generates it.

[0005]** a method is shown in drawing 31 (a) with the conventional exposure method -- as -- the directivity sigma of the illumination light (the ratio of breadth d of the illumination light on this pupil to the pupil diameter D of a projection optical system.) Namely, to sigma=d/D having used about 0.5, as shown in drawing 31 (b), make breadth of the illumination light on a pupil into the shape of zona orbicularis, and the outer diameter and inside diameter of this zona orbicularis to the pupil diameter D, respectively for example, by using 0.7 and about 0.5, MTF (Moduration Transfer Function) of the high frequency portion of a pattern is made high. Although it becomes high resolution compared with the lighting of this result former, compared with the phase shift method of **, resolving is low.

[0006]** The method arranges the breadth of the illumination light on the pupil of a projection optical system to a four-point vertical angle, as shown in drawing 31 (c). By doing in this way, even if resolution compares with the conventional lighting of conventional sigma=0.5 low compared with the zona-orbicularis lighting of ** to xy directional pattern in a figure, resolution will become low.

[0007]

[Problem(s) to be Solved by the Invention]This invention tends to solve the aforementioned problem of the above-mentioned conventional method, especially the various describing [above] super resolution methods studied briskly now.

[0008]It is as follows when a technical problem is arranged here. ** Although the conventional phase shift method is a method of obtaining the highest resolution, in the present super resolution method, since the pattern in which a design like a two-dimensional pattern is impossible exists if it is going to maintain this resolution, it becomes a serious obstacle on LSI design manufacture. ** As for zona-orbicularis illumination, high resolution is not obtained compared with the method of **. ** Although resolution of a method is low compared with ** and the resolution of the pattern of the xy direction is high compared with **, the resolution of xy and a 45-degree pattern gets remarkably bad.

[0009]The purpose of this invention is to provide the exposure method using the polarization mask and it which are realized without generating a pattern whose design of the conventional phase shift method of ** and the resolution more than equivalent becomes impossible, and the projection aligner using it.

[0010]

[Means for Solving the Problem]To achieve the above objects, a polarization mask (or polarization reticle) in which an original picture pattern of a request of light from an illumination light source for exposure was drawn in this invention is had and irradiated with desired directivity, The transmitted light or catoptric light of the above-mentioned polarization mask is projected on an object to be exposed through a projection optical system, and the following means are given when exposing an image from the above-

mentioned original picture pattern.

[0011]That is, the directivity of the above-mentioned illumination light is considered as what is called zona-orbicularis lighting or way lighting to shoot, and a polarization mask of pattern dependence which makes a polarization characteristic according to a direction which a pattern on the above-mentioned polarization mask turns to give illumination light which penetrated this pattern is used. Exposing light of the above-mentioned zona-orbicularis lighting or way lighting to shoot on a pupil of the above-mentioned projection optical system at this time is good for that polarization condition to use the symmetry of revolution in general to a pupil center, when there is no above-mentioned polarization mask. It is good for a polarization condition to arrange a polarizing element (or light analysis element) which is the symmetry of revolution in general to a pupil center near the pupil of the above-mentioned projection optical system.

[0012]As a polarization mask of the above-mentioned pattern dependence, whether a tangential direction of edge of a pattern on a mask and a polarization direction of light which penetrated this pattern of the above-mentioned illumination light being parallel in general, and a mask which intersects perpendicularly are used. Although a pattern on a mask is penetrated the portion A which penetrates illumination light, and a little, the above-mentioned purpose can be attained by using the above-mentioned polarization mask which comprises the portion B which shades mostly. receiving a portion of the above A and B at this time -- an account of the upper -- amplitude transmittance of the portion B which shades mostly is good to make it to 30% or less to amplitude transmittance of the penetrating above-mentioned portion A. One side passes along a pupil of the above-mentioned projection optical system among primary [**] lights of the diffracted light from the minimum pattern on a polarization mask in which the directivity of the above-mentioned way lighting which is zona-orbicularis-illuminated or is shot was illuminated by this irradiation light, and another side is kept from passing along a pupil.

[0013]A means to give a polarization characteristic on the above-mentioned polarization mask is realizable using minute slit structure. The above-mentioned minute slit structure is made into structure where a thin line of the detailed singular number or plurality is drawn along a line of edge of a pattern transparent part. Width of this detailed line is good to use or less about 1 of the wavelength lambda of illumination light / 2. This thin line is good to make it material which was excellent in conductivity and was not based on wavelength of exposing light but the complex index of refraction n and whose optical absorption coefficient k are stable.

[0014]By using an above-mentioned method, a detailed integrated circuit of pattern structure unrealizable by the conventional phase-shifter method is exposed. With what is called zona-orbicularis lighting or way lighting to shoot, the directivity of the conventional illumination light cannot be resolved and exposes a detailed integrated circuit which moreover does not have restrictions of the direction of a pattern.

[0015]Namely, at least a pattern of this detailed integrated circuit including a recurrent

pattern the line width W of this recurrent pattern, or the repetition pitch p. When a numerical aperture of lambda and a projection optical system is set to NA for an exposure wavelength, 0.25 lambda/NA<W <0.5 lambda/NA or 0.5 lambda/NA<p <1.0 lambda/NA is filled. A pattern of this detailed integrated circuit, A pattern which has an angle of about 45 degrees with a 2-way which intersects perpendicularly is included, and a pattern which cannot be exposed by the conventional phase-shifter method is included, And when the line width W of a recurrent pattern or the repetition pitch p sets a numerical aperture of lambda and a projection optical system to NA for an exposure wavelength including a recurrent pattern, 0.25 lambda/NA<W <0.5 lambda/NA or 0.5 lambda/NA<p <1.0 lambda/NA is filled.

[0016]An operation of this invention is explained using drawing 32 thru/or drawing 36.

[0017]As shown in drawing 32, in the case of a pattern long to a y direction, linear polarization of through and a x direction presupposes that it does not let linear polarization to which this pattern vibrates to a y direction pass. The directivity of illumination light which irradiates with a polarization mask in which this pattern was drawn, Light flux B_1 from for [which irradiates with this pattern in zona-orbicularis lighting which is what is called zona-orbicularis lighting or the way lighting to shoot, for example is shown in a figure] all directions, Considering B_2, B_3, B_4, B_5, B_6, B_7, and B_8. these -- light -- polarization -- a mask -- there is nothing -- a case -- respectively -- a projection lens -- a pupil -- a top -- B -- $_1$ -- ' -- B -- $_2$ -- ' -- B -- $_3$ -- ' -- B -- $_4$ -- ' -- B -- $_5$ -- ' -- B -- $_6$ -- ' -- B -- $_7$ -- ' -- B -- $_8$ -- ' -- a position -- resulting .

[0018]Now, polarization of eight light flux is vertical to an optic axis of a projection optical system, and if it is made to intersect perpendicularly with a line which passes along an optic axis, light flux of B_1 and B_5 will penetrate a pattern of a y direction among these eight light flux, but light flux of B_3 and B_7 hardly penetrates this pattern. B_2 which exists in the middle, B_4, B_6, and B_8 will be penetrated mostly 1/2. As for light flux of B_1 and B_5, the chief ray after passing a pattern results in pupil top B_1" and B_5" of a projection optical system, and the diffracted light spreads in a surrounding x direction of zero-order light B_1' and B_5'.

[0019]If the diffracted light of this x direction can penetrate a pupil in the wide range, it is known well that high resolving will be obtained. Therefore, will pass only the narrow range of the diffracted light on a pupil, but will drop resolution on this invention so that light flux of B_1 and B_5 may pass most patterns of a y direction, high resolution may be given and light flux of B_3 and B_7 may be known clearly from this explanation, but. This light flux becomes possible [exposing a minute pattern], without dropping resolution, in order to hardly pass this pattern. Although light of B_2, B_4, B_6, and B_8 is illumination light of the conventional ** and resolution is not so good as light flux of B_1 and B_5, since intensity of a passing beam is one half, it becomes dominant [resolution by light flux of B_1 and B_5].

[0020]Since only illumination light to which resolution becomes high most is used effectively, by this invention, resolution which was not able to be attained by a method of the conventional **** comes to be obtained, so that the above explanation may also show. The polarizability of above-mentioned illumination light and the polarization penetration characteristic by the direction of a pattern realize high resolution similarly to a pattern which turned to not only a pattern of a y direction but arbitrary directions. It not being dependent on the direction of this pattern or how to be located in a line, and high resolution's being obtained is not having realized in the conventional phase shift method of **.

[0021]In order to compare an operation of this invention with the conventional super resolution method, a method of **** and a thing which searched for a resolving situation of a pattern obtained by this invention with a simulation are shown in drawing 33, drawing 34, drawing 35, and drawing 36. in order to show an effect of this invention, as for 0.25 micrometer and exposure, pattern width to expose is [the numerical aperture NA of wavelength of 365 nm and a projection optical system] 0.57 by i line of a mercury lamp. Drawing 33 is in a resolving situation in zona-orbicularis lighting, and is understood that separation of a pattern is bad also in a position of a focusing point.

[0022]Drawing 34 is in a resolving situation in method lighting of slanting of ** to a pattern of the xy direction, if compared with a case of zona-orbicularis lighting, it is improved, but pattern separation worsens by 0.5-micrometer defocusing. However, in a resolving situation of a 45-degree pattern, resolving has deteriorated compared with zona-orbicularis lighting in the xy direction of drawing 35. Drawing 36 is in a resolving situation of a pattern obtained with a mask when a ratio of transmissivity of a transparent part used by the usual mask, i.e., drawing 33, and 34 and 35 with an exposure method of this invention and a shade part is infinite, and it turns out that a good image is acquired in a wide focus range compared with drawing 33, drawing 34, and drawing 35.

[0023]Although a pattern on a mask penetrates the portion A which penetrates illumination light, and a little, the portion B which shades mostly is comprised and resolution of light which penetrates A and B improves further on this mask zona-orbicularis lighting or by [which shoot] carrying out way lighting using a mask in which 180 degrees of phases differ mutually. At this time, to portions of A and B, if it is made to 30% or less to complex amplitude transmissivity of the portion A which penetrates complex amplitude transmissivity of the portion B which shades mostly, high resolution will be obtained. If it is made to especially 22%, separation between patterns will become good most.

[0024]This is because both luminous intensities become mutual almost equal and separation of a recurrent pattern becomes the largest best in contrast of interference by both lights, when complex amplitude transmissivity of a shade part of a mask becomes 22% in zero-order light and primary light by zona-orbicularis lighting or way lighting to shoot.

[0025]If it is made for a polarization condition on a pupil of a projection optical system of illumination light when it presupposes that there is no mask temporarily using a mask of this

invention to be the symmetry of revolution in general to a pupil center, even if it does not use zona-orbicularis lighting or way lighting to shoot, it will become possible to expose a pattern better than resolution obtained by a conventional method. A relative fall of contrast of a high frequency region of a resolving pattern from which the directivity sigma of lighting had happened conventionally in this case especially even when big does not occur, but it becomes possible to expose in high resolution.

[0026]

[Embodiment of the Invention]Drawing 1 is Example 1 of this invention, and is an example which forms a recurrent pattern using negative resist. Drawing 1 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 1 (a) is shown in drawing 1 (b). Drawing 1 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 1 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 1 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out.

[0027]W of drawing 1 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2. It excels in the detailed light-shielding film pattern 205 at the conductivity of aluminum, tin, etc., and does not depend on wavelength, but the complex index of refraction n and the optical absorption coefficient k use a fixed light-shielding film material.

[0028]The detailed light-shielding film pattern 205 uses and forms EB (ElectronBeam) drawing device in the transparent substrates 2032, such as silica glass. The half-tone phase shifter 204 uses EB drawing device for transparent substrate 2031 with the another detailed light-shielding film pattern 205, is formed, and makes light transmittance of this portion (optical shade part 202) about 5 to 20%. A monolayer or multilayer half-tone is used for the half-tone phase shifter 204 with the different thing and single material of two-layer structure of material which consist of the absorber (it is equivalent to a shade part) and diacid-ized silicon system shifter which made thickness of chromium thin. Material has a chromium system (CrO, CrON), a molybdenum system (MoSiO, MoSiON), and a silicon nitride system (SiN).

[0029]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 2032 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent substrate 2031 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the complex amplitude transmissivity of the light immediately after a penetration of this polarization mask

becomes like drawing 1 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.

[0030]When [of the detailed light-shielding film pattern 205] the portion of the boundary of an outside pattern and the half-tone phase shifter 204 controls the transmissivity of the half-tone phase shifter 204 most, contrast can be raised as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0031]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 1 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of negative resist, only the portion of the width W of the light transmission section 201 remains at the time of development, and it serves as NEGAREJISUTOPATAN shown in drawing 1 (d). What etched NEGAREJISUTOPATAN shown in drawing 1 (d) is a circuit pattern shown in drawing 1 (e).

[0032]Thus, it becomes possible to expose the pattern of the high resolution which was excellent in pattern separation by combining the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity.

[0033]The same effect as drawing 1 is acquired also in the example which formed phase-shifter material in the transparent substrate 2031, and formed half-tone material in the transparent substrate 2032, and the example in which the half-tone phase shifter 204 and the detailed light-shielding film pattern 205 were formed on the same side of a transparent substrate of one sheet. Also when a positive resist is used, the same effect as drawing 1 is acquired.

[0034]It is a top view of the circuit pattern on a wafer when drawing 2 (a) and (b) considers it as the top view of the polarization mask of drawing 1, drawing 2 (c) uses the polarization mask of drawing 1 as the original edition and projection exposure is carried out.

[0035]As shown in drawing 2 (a), the half-tone phase shifter 204 and the mask superposition mark 210 are formed in the transparent substrate 2031. The detailed light-shielding film pattern 205 and the mask superposition mark 210 are formed in the transparent substrate 2032 of drawing 2 (b). Therefore, if you read the center coordinates of each mask superposition mark 210, you make it pile each other up and it positions beforehand with the measuring device when piling up and exposing the transparent substrates 2031 and 2032, As the relative position gap with the half-tone phase shifter 204 and the detailed light-shielding film pattern 205 stops occurring and it is shown in drawing 2 (c), it becomes possible to expose the pattern of the high resolution which was excellent in

pattern separation.

[0036]Drawing 3 is Example 2 of this invention, and is an example which forms a recurrent pattern using negative resist. Drawing 3 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 3 (a) is shown in drawing 3 (b). Drawing 3 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 3 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 3 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out.

[0037]W of drawing 3 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0038]The detailed light-shielding film pattern 205 uses and forms EB drawing device in the transparent substrate 2032. The half-tone phase shifter 204 uses EB drawing device for transparent substrate 2031 with the another detailed light-shielding film pattern 205, is formed, and makes light transmittance of this portion (optical shade part 202) about 5 to 20%. The light-shielding film pattern 211 is formed in the field which furthermore has the detailed light-shielding film pattern 205 of the transparent substrate 2032 by the same method as the position detached a little. The same material as the detailed light-shielding film pattern 205 is used for the light-shielding film pattern 211. It arranges so that the edge inside the light-shielding film pattern 211 may become outside for a while rather than the edge inside the half-tone phase shifter 204.

[0039]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 2032 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent substrate 2031 is penetrated only about 5 to 30%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed. As for the portion by which the light-shielding film pattern 211 is arranged, complex amplitude is set to 0.

[0040]The complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 3 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.

[0041]By controlling the transmissivity of the half-tone phase shifter 204, the portion of the boundary of the pattern of the outside of the detailed light-shielding film pattern 205 and the inside and the half-tone phase shifter 204 can raise contrast, as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.
[0042]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 3 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of negative resist, the portion of the width W of the light transmission section 201 remains at the time of development, and serves as NEGAREJISUTOPATAN shown in drawing 3 (d). What etched NEGAREJISUTOPATAN shown in drawing 3 (d) is a circuit pattern shown in drawing 3 (e).
[0043]Thus, when width deltaw of an opening combines the detailed light-shielding film pattern 205 and the light-shielding film pattern 211 which are about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity, The contrast of an outside recurrent pattern portion becomes high, and it becomes possible to expose the pattern of the high resolution which was excellent in separation.
[0044]The example which formed in the transparent substrate 2032 the half-tone material in which the transparent substrate 2031 and the light-shielding film pattern 211 appeared phase-shifter material, The same effect as drawing 3 is acquired also in the example in which the half-tone phase shifter 204 in which the light-shielding film pattern 211 appeared, and the detailed light-shielding film pattern 205 were formed on the same side of a transparent substrate of one sheet. Also when a positive resist is used, the same effect as drawing 3 is acquired.
[0045]Drawing 4 (a) and (b) is a top view of the polarization mask of drawing 3. Drawing 4 (c) is a top view of the circuit pattern on a wafer when the polarization mask of drawing 3 is used as the original edition and projection exposure is carried out. As shown in drawing 4 (a), the half-tone phase shifter 204 and the mask superposition mark 210 are formed in the transparent substrate 2031. The detailed light-shielding film pattern 205 and the light-shielding film pattern 211, and the mask superposition mark 210 are formed in the transparent substrate 2032 of drawing 4 (b). Therefore, if you read the center coordinates of each mask superposition mark 210, you make it pile each other up and it positions beforehand with the measuring device when piling up and exposing the transparent substrates 2031 and 2032, It becomes possible to expose the pattern of the high resolution which was excellent in pattern separation as the relative position gap with the half-tone phase shifter 204, the detailed light-shielding film pattern 205, and the light-shielding film pattern 211 stopped generating and shown in drawing 4 (c).
[0046]Drawing 5 is Example 3 of this invention, and is an example which forms a recurrent pattern using negative resist. Drawing 5 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the

illumination light which enters from the lower part of drawing 5 (a) is shown in drawing 5 (b). Drawing 5 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 5 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 5 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out.

[0047]W of drawing 5 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0048]The transparent membrane material 212 is first vapor-deposited by a sputtering technique to the transparent substrate 203. Vacuum evaporation thickness uses more than d_1=1micrometer, in order to improve the polarization characteristic of the detailed light-shielding film pattern 205. Next, with a converged ion beam processing device, the detailed line for detailed light-shielding film pattern 205 is carved. It excels in the conductivity of aluminum, tin, etc. after the end of detailed line processing, and does not depend on wavelength, but the complex index of refraction n and the optical absorption coefficient k vapor-deposit a fixed light-shielding film material by a sputtering technique. Then, polishing work, such as CMP (Chemical Mechanical Polishing), is performed, and it is made for light-shielding film material to remain only in a detailed line part. On the transparent membrane material 212, the half-tone phase shifter 204 uses EB drawing device, is formed, and makes light transmittance of this portion (optical shade part 202) about 5 to 20%. Thickness d_2 uses about [of thickness d_1 of the transparent membrane material 212] 1/10.

[0049]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 203 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent membrane material 212 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed.

[0050]The complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 5 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.

[0051]By controlling the transmissivity of the half-tone phase shifter 204, the portion of the

boundary of the pattern of the outside of the detailed light-shielding film pattern 205 and the inside and the half-tone phase shifter 204 can raise contrast, as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0052]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 5 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of negative resist, the portion of the width W of the light transmission section 201 remains at the time of development, and serves as NEGAREJISUTOPATAN shown in drawing 5 (d). What etched NEGAREJISUTOPATAN shown in drawing 5 (d) is a circuit pattern shown in drawing 5 (e).

[0053]Thus, it becomes possible to expose the pattern of the high resolution which was excellent in separation by combining the transparent membrane material 212 containing the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity.

[0054]Also when a positive resist is used, the same effect as drawing 5 is acquired.

[0055]It is a top view of the circuit pattern on a wafer when drawing 6 (a) is used as the top view of the polarization mask of drawing 5, drawing 6 (b) uses the polarization mask of drawing 5 as the original edition and projection exposure is carried out.

[0056]As shown in drawing 6 (a), the transparent membrane material 212 and the half-tone phase shifter 204 containing the detailed light-shielding film pattern 205 are formed in the transparent substrate 203. Therefore, if the transparent substrate 203 is exposed as it is, it will become possible to expose the pattern of the high resolution which was excellent in pattern separation as shown in drawing 6 (b).

[0057]Drawing 7 is Example 4 of this invention, and is an example which forms a recurrent pattern using negative resist. Drawing 7 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 7 (a) is shown in drawing 7 (b). Drawing 7 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 7 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 7 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out.

[0058]W of drawing 7 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0059]The transparent membrane material 212, the detailed light-shielding film pattern 205, and the half-tone phase shifter 204 are formed in the transparent substrate 203 by the same method as drawing 5. The light-shielding film pattern 211 is formed with EB drawing device on the half-tone phase shifter 204. The edge inside the light-shielding film pattern 211 is arranged outside the edge inside the half-tone phase shifter 204.
[0060]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 203 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent membrane material 212 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed. Since the portion in which the light-shielding film pattern 211 is formed is shaded thoroughly, complex amplitude is set to 0.
[0061]The complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 7 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.
[0062]By controlling the transmissivity of the half-tone phase shifter 204, the portion of the boundary of the pattern of the outside of the detailed light-shielding film pattern 205 and the inside and the half-tone phase shifter 204 can raise contrast, as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.
[0063]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 7 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of negative resist, the portion of the width W of the light transmission section 201 remains at the time of development, and serves as NEGAREJISUTOPATAN shown in drawing 7 (d). What etched NEGAREJISUTOPATAN shown in drawing 7 (d) is a circuit pattern shown in drawing 7 (e).
[0064]Thus, by combining the transparent membrane material 212 containing the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 and the light-shielding film pattern 211 which controlled transmissivity, The contrast of the edge part of an outside recurrent pattern improves most, and it becomes possible to expose the pattern of the high resolution which was excellent in separation.
[0065]Also when a positive resist is used, the same effect as drawing 7 is acquired.
[0066]It is a top view of the circuit pattern on a wafer when drawing 8 (a) is used as the top view of the polarization mask of drawing 7, drawing 8 (b) uses the polarization mask of

drawing 7 as the original edition and projection exposure is carried out.

[0067]As shown in drawing 8 (a), the transparent membrane material 212, the half-tone phase shifter 204, and the light-shielding film pattern 211 containing the detailed light-shielding film pattern 205 are formed in the transparent substrate 203. Therefore, if the transparent substrate 203 is exposed as it is, it will become possible to expose the pattern of the high resolution which was excellent in pattern separation as shown in drawing 8 (b).

[0068]Drawing 9 is Example 5 of this invention, and is an example which forms an isolated pattern using negative resist. Drawing 9 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 9 (a) is shown in drawing 9 (b). Drawing 9 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 9 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 9 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out.

[0069]W of drawing 9 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0070]The detailed light-shielding film pattern 205 uses and forms EB drawing device in the transparent substrate 2032. The half-tone phase shifter 204 uses EB drawing device for transparent substrate 2031 with the another detailed light-shielding film pattern 205, is formed, and makes light transmittance of this portion (optical shade part 202) about 5 to 20%.

[0071]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 2032 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent substrate 2031 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 9 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line. Since a pattern does not exist in the outside of the detailed light-shielding film pattern 205, complex amplitude transmissivity will be 100%.

[0072]When [of the detailed light-shielding film pattern 205] the portion of the boundary of

an outside pattern and the half-tone phase shifter 204 controls the transmissivity of the half-tone phase shifter 204 most, contrast can be raised as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0073]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 9 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of negative resist, only the portion of the width W of the light transmission section 201 remains at the time of development, and it serves as NEGAREJISUTOPATAN shown in drawing 9 (d). What etched NEGAREJISUTOPATAN shown in drawing 9 (d) is a circuit pattern shown in drawing 9 (e).

[0074]Thus, it becomes possible to expose the pattern of the high resolution which was excellent in pattern separation by combining the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity. The same effect as drawing 9 is acquired also in the example which formed phase-shifter material in the transparent substrate 2031, and formed half-tone material in the transparent substrate 2032, and the example in which the half-tone phase shifter 204 and the detailed light-shielding film pattern 205 were formed on the same side of a transparent substrate of one sheet.

[0075]Drawing 10 (a) and (b) is a top view of the polarization mask of drawing 9.

[0076]As shown in drawing 10 (a), the half-tone phase shifter 204 and the mask superposition mark 210 are formed in the transparent substrate 2031. The detailed light-shielding film pattern 205 and the mask superposition mark 210 are formed in the transparent substrate 2032 of drawing 10 (b). Therefore, if you read the center coordinates of each mask superposition mark 210, you make it pile each other up and it positions beforehand with the measuring device when piling up and exposing the transparent substrates 2031 and 2032, It becomes possible to expose the pattern of the high resolution which the relative position gap with the half-tone phase shifter 204 and the detailed light-shielding film pattern 205 stops having occurred at, and was excellent in pattern separation.

[0077]Drawing 11 is Example 6 of this invention, and is an example which forms an isolated pattern using negative resist. Drawing 11 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 11 (a) is shown in drawing 11 (b). Drawing 11 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 11 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 11 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. W of drawing 11 (a) is the width of

the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0078]The detailed light-shielding film pattern 205 uses and forms EB drawing device in the transparent substrate 2032. The half-tone phase shifter 204 uses EB drawing device for transparent substrate 2031 with the another detailed light-shielding film pattern 205, is formed, and makes light transmittance of this portion (optical shade part 202) about 5 to 20%. The light-shielding film pattern 211 is formed in the field which furthermore has the detailed light-shielding film pattern 205 of the transparent substrate 2032 by the same method as the position detached a little. It arranges so that the edge inside the light-shielding film pattern 211 may become outside for a while rather than the edge inside the half-tone phase shifter 204.

[0079]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 2032 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent substrate 2031 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed. As for the portion by which the light-shielding film pattern 211 is arranged, complex amplitude is set to 0.

[0080]The complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 11 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.

[0081]By controlling the transmissivity of the half-tone phase shifter 204, the portion of the boundary of the pattern of the outside of the detailed light-shielding film pattern 205 and the half-tone phase shifter 204 can raise contrast, as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0082]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 11 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of negative resist, the portion of the light transmission section 201 (W) remains at the time of development, and serves as NEGAREJISUTOPATAN shown in drawing 11 (d). What etched NEGAREJISUTOPATAN shown in drawing 11 (d) is a circuit pattern shown in drawing 11 (e).

[0083]Thus, when width deltaw of an opening combines the detailed light-shielding film

pattern 205 and the light-shielding film pattern 211 which are about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity, The contrast of the edge part of an isolated pattern becomes high, and it becomes possible to expose the pattern of the high resolution which was excellent in separation.

[0084]The example which formed in the transparent substrate 2032 the half-tone material in which the transparent substrate 2031 and the light-shielding film pattern 211 appeared phase-shifter material, The same effect as drawing 11 is acquired also in the example in which the half-tone phase shifter 204 in which the light-shielding film pattern 211 appeared, and the detailed light-shielding film pattern 205 were formed on the same side of a transparent substrate of one sheet.

[0085]Also when a positive resist is used, the same effect as drawing 11 is acquired.

[0086]Drawing 12 (a) and (b) is a top view of the polarization mask of drawing 11. As shown in drawing 12 (a), the half-tone phase shifter 204 and the mask superposition mark 210 are formed in the transparent substrate 2031. The detailed light-shielding film pattern 205 and the light-shielding film pattern 211, and the mask superposition mark 210 are formed in the transparent substrate 2032 of drawing 12 (b). Therefore, if you read the center coordinates of each mask superposition mark 210, you make it pile each other up and it positions beforehand with the measuring device when piling up and exposing the transparent substrates 2031 and 2032, It becomes possible to expose the pattern of the high resolution which the relative position gap with the half-tone phase shifter 204, the detailed light-shielding film pattern 205, and the light-shielding film pattern 211 stops having occurred at, and was excellent in pattern separation.

[0087]Drawing 13 is a top view of the isolated pattern on a wafer when the polarization mask of drawing 11 is used as the original edition and projection exposure is carried out.

[0088]Drawing 14 is Example 7 of this invention, and is an example which forms an isolated pattern using negative resist. Drawing 14 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 14 (a) is shown in drawing 14 (b). Drawing 14 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 14 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 14 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. W of drawing 14 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0089]The transparent membrane material 212, the detailed light-shielding film pattern 205, and the half-tone phase shifter 204 are formed in the transparent substrate 203 by the

same method as drawing 5.

[0090]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 203 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent membrane material 212 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed.

[0091]The complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 14 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.

[0092]By controlling the transmissivity of the half-tone phase shifter 204, the portion of the boundary of the pattern of the outside of the detailed light-shielding film pattern 205 and the half-tone phase shifter 204 can raise contrast, as shown in drawing 23.Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0093]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 14 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of negative resist, the portion of the width W of the light transmission section 201 remains at the time of development, and serves as NEGAREJISUTOPATAN shown in drawing 14 (d). What etched NEGAREJISUTOPATAN shown in drawing 14 (d) is a circuit pattern shown in drawing 14 (e).

[0094]Thus, it becomes possible to expose the pattern of the high resolution which was excellent in separation by combining the transparent membrane material 212 containing the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity.

[0095]It is a top view of the circuit pattern on a wafer when drawing 15 (a) is used as the top view of the polarization mask of drawing 14, drawing 15 (b) uses the polarization mask of drawing 14 as the original edition and projection exposure is carried out.

[0096]As shown in drawing 15 (a), the transparent membrane material 212 and the half-tone phase shifter 204 containing the detailed light-shielding film pattern 205 are formed in the transparent substrate 203. Therefore, if the transparent substrate 203 is exposed as it is, it will become possible to expose the pattern of the high resolution which was excellent in pattern separation as shown in drawing 15 (b).

[0097]Drawing 16 is Example 8 of this invention, and is an example which forms an isolated

pattern using negative resist. Drawing 16 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 16 (a) is shown in drawing 16 (b). Drawing 16 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 16 (d) shows the sectional view of NEGAREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 16 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. W of drawing 16 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0098]The transparent membrane material 212, the detailed light-shielding film pattern 205, and the half-tone phase shifter 204 are formed in the transparent substrate 203 by the same method as drawing 5. The light-shielding film pattern 211 is formed with EB drawing device on the half-tone phase shifter 204. The edge inside the light-shielding film pattern 211 is arranged outside the edge inside the half-tone phase shifter 204.

[0099]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 203 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent membrane material 212 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed. Since the portion in which the light-shielding film pattern 211 is formed is shaded thoroughly, complex amplitude is set to 0.

[0100]The complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 16 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.

[0101]By controlling the transmissivity of the half-tone phase shifter 204, the portion of the boundary of the pattern of the outside of the detailed light-shielding film pattern 205 and the half-tone phase shifter 204 can raise contrast, as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0102]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 16 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the

development limit of negative resist, the portion of the width W of the light transmission section 201 remains at the time of development, and serves as NEGAREJISUTOPATAN shown in drawing 16 (d). What etched NEGAREJISUTOPATAN shown in drawing 16 (d) is a circuit pattern shown in drawing 16 (e).

[0103]Thus, by combining the transparent membrane material 212 containing the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 and the light-shielding film pattern 211 which controlled transmissivity, The contrast of the edge part of an isolated pattern improves and it becomes possible to expose the pattern of the high resolution which was excellent in separation.

[0104]It is a top view of the circuit pattern on a wafer when drawing 17 (a) is used as the top view of the polarization mask of drawing 16, drawing 17 (b) uses the polarization mask of drawing 16 as the original edition and projection exposure is carried out.

[0105]As shown in drawing 17 (a), the transparent membrane material 212, the half-tone phase shifter 204, and the light-shielding film pattern 211 containing the detailed light-shielding film pattern 205 are formed in the transparent substrate 203. Therefore, if the transparent substrate 203 is exposed as it is, it will become possible to expose the pattern of the high resolution which was excellent in pattern separation as shown in drawing 17 (b).

[0106]Drawing 18 is Example 9 of this invention, and is an example which forms an isolated pattern using a positive resist. Drawing 18 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 18 (a) is shown in drawing 18 (b). Drawing 18 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 18 (d) shows the sectional view of POJIREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 18 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out.

[0107]W of drawing 18 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0108]The detailed light-shielding film pattern 205 uses and forms EB drawing device in the transparent substrate 2032. The half-tone phase shifter 204 uses EB drawing device for transparent substrate 2031 with the another detailed light-shielding film pattern 205, is formed, and makes light transmittance of this portion (optical shade part 202) about 5 to 20%.

[0109]Polarization of the edge direction of a pattern penetrates the illumination light which

enters from the lower part of the transparent substrate 2032 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent substrate 2031 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 18 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line. Since a pattern does not exist in the outside of the detailed light-shielding film pattern 205, complex amplitude transmissivity will be 100%.

[0110]When [of the detailed light-shielding film pattern 205] the portion of the boundary of an inside pattern and the half-tone phase shifter 204 controls the transmissivity of the half-tone phase shifter 204 most, contrast can be raised as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0111]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on a wafer becomes like drawing 18 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of a positive resist, the portion without the width W of the light transmission section 201 and the pattern of the outside is removed at the time of development, and serves as POJIREJISUTOPATAN shown in drawing 18 (d). What etched POJIREJISUTOPATAN shown in drawing 18 (d) is a circuit pattern shown in drawing 18 (e).

[0112]Thus, it becomes possible to expose the pattern of the high resolution which was excellent in pattern separation by combining the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity. The same effect as drawing 18 is acquired also in the example which formed phase-shifter material in the transparent substrate 2031, and formed half-tone material in the transparent substrate 2032, and the example in which the half-tone phase shifter 204 and the detailed light-shielding film pattern 205 were formed on the same side of a transparent substrate of one sheet.

[0113]Drawing 19 (a) and (b) is a top view of the polarization mask of drawing 18. As shown in drawing 19 (a), the half-tone phase shifter 204 and the mask superposition mark 210 are formed in the transparent substrate 2031. The detailed light-shielding film pattern 205 and the mask superposition mark 210 are formed in the transparent substrate 2032 of drawing 19 (b). Therefore, if you read the center coordinates of each mask superposition mark 210, you make it pile each other up and it positions beforehand with the measuring device when piling up and exposing the transparent substrates 2031 and 2032, It becomes

possible to expose the pattern of the high resolution which the relative position gap with the half-tone phase shifter 204 and the detailed light-shielding film pattern 205 stops having occurred at, and was excellent in pattern separation.

[0114]Drawing 20 is Example 10 of this invention, and is an example which forms an isolated pattern using a positive resist. Drawing 20 (a) is a sectional view of the polarization mask of this invention. The complex amplitude transmissivity of the transmitted light of the illumination light which enters from the lower part of drawing 20 (a) is shown in drawing 20 (b). Drawing 20 (c) shows the light intensity on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 20 (d) shows the sectional view of POJIREJISUTOPATAN on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. Drawing 20 (e) shows the sectional view of the circuit pattern on a wafer when this polarization mask is used as the original edition and projection exposure is carried out. W of drawing 20 (a) is the width of the light transmission section 201 which a pattern exposes, and at least one conductive detailed light-shielding film pattern 205 which has a polarization characteristic in this exists. This number is chosen so that width deltaw of the opening of the light transmission section 201 may become about [of an exposure wavelength] 1/2.

[0115]The transparent membrane material 212, the detailed light-shielding film pattern 205, and the half-tone phase shifter 204 are formed in the transparent substrate 203 by the same method as drawing 5.

[0116]Polarization of the edge direction of a pattern penetrates the illumination light which enters from the lower part of the transparent substrate 203 in a portion with the detailed light-shielding film pattern 205, and the portion with the half-tone phase shifter 204 on the transparent membrane material 212 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed. The transmissivity of the portion without the pattern of the transparent membrane material 212 will be 100%.

[0117]The complex amplitude transmissivity of the light immediately after a penetration of this polarization mask becomes like drawing 20 (b). Since complex amplitude is set to 0 as for the portion, as for, the complex amplitude transmissivity of the portion of the light transmission section 201 has the detailed light-shielding film pattern 205, a theory top serves as transmissivity distribution as shown by the dotted line, but in an exposure wavelength, in order not to resolve the detailed light-shielding film pattern 205, it serves as distribution as actually shown as the solid line.

[0118]By controlling the transmissivity of the half-tone phase shifter 204, the portion of the boundary of the pattern inside the detailed light-shielding film pattern 205 and the half-tone phase shifter 204 can raise contrast, as shown in drawing 23. Therefore, it becomes the big complex amplitude transmissivity of the contrast of the portion of the edge of the width W of a pattern to resolve as the whole.

[0119]Since light intensity distribution is proportional to the square of complex amplitude

transmissivity, the light intensity on a wafer becomes like drawing 20 (c). Since the light intensity of the portion mostly shaded by the half-tone phase shifter 204 is lower than the development limit of a positive resist, the portion without the portion and pattern of the width W of the light transmission section 201 is removed at the time of development, and serves as POJIREJISUTOPATAN shown in drawing 20 (d). What etched POJIREJISUTOPATAN shown in drawing 20 (d) is a circuit pattern shown in drawing 20 (e).

[0120]Thus, it becomes possible to expose the pattern of the high resolution which was excellent in separation by combining the transparent membrane material 212 containing the detailed light-shielding film pattern 205 whose width deltaw of an opening is about [of an exposure wavelength] 1/2, and the half-tone phase shifter 204 which controlled transmissivity.

[0121]It is a top view of the circuit pattern on a wafer when drawing 21 (a) is used as the top view of the polarization mask of drawing 20, drawing 21 (b) uses the polarization mask of drawing 20 as the original edition and projection exposure is carried out.

[0122]As shown in drawing 21 (a), the transparent membrane material 212 and the half-tone phase shifter 204 containing the detailed light-shielding film pattern 205 are formed in the transparent substrate 203. Therefore, if the transparent substrate 203 is exposed as it is, it will become possible to expose the pattern of the high resolution which was excellent in pattern separation as shown in drawing 21 (b).

[0123]Drawing 22 is a top view of the isolated pattern on a wafer when drawing 18 and the polarization mask of drawing 20 are used as the original edition and projection exposure is carried out.

[0124]Drawing 23 is a figure showing the principle of a half-tone type phase shifter. The sectional view of a mask in which drawing 23 (a) formed the half-tone type phase shifter, The complex amplitude transmissivity of the light on a wafer when drawing 23 (b) is made into the complex amplitude transmissivity of the mask transmitted light, drawing 23 (c) uses a mask as the original edition and projection exposure is carried out, and drawing 23 (d) show the light intensity distribution on a wafer when said mask is used as the original edition and projection exposure is carried out.

[0125]In drawing 23 (a), the half-tone phase shifter 204 is formed in the transparent substrate 203 with EB drawing device, and the portion without the portion of the optical shade part 202 and 204 half-tone phase shifter with the half-tone phase shifter 204 serves as the light transmission section 201.

[0126]The illumination light which enters from the lower part of the transparent substrate 203 is penetrated 100% in a portion without the half-tone phase shifter 204, and the portion with the half-tone phase shifter 204 is penetrated only about 5 to 20%, as described above. Since a 180-degree phase shifter is provided in the half-tone phase shifter 204, the phase of the light of this portion is reversed.

[0127]The complex amplitude transmissivity of the light immediately after a penetration of this mask becomes like drawing 23 (b). Although the complex amplitude transmissivity of

the portion of the light transmission section 201 will be 100%, the portion with the half-tone phase shifter 204 serves as distribution as shown as the solid line, in order that it may penetrate only about 5 to 20% as described above, but a phase may be reversed.

[0128]The complex amplitude transmissivity of the light on a wafer when a mask is used as the original edition and projection exposure is carried out becomes like drawing 23 (c). The complex amplitude transmissivity of only the portion of the light transmission section 201 becomes like the dotted-line part 53 in the complex amplitude transmissivity of only the dotted-line part 52 and the optical shade part 202. Since the optical shade part 202 and the light transmission section 201 are continuing, they serve as distribution of the sum of the dotted-line part 52 and the dotted-line part 53 actually, and serve as transmissivity distribution like the real line part 51. Therefore, if the transmissivity of the half-tone phase shifter 204 is adjusted, complex amplitude transmissivity of the light on the wafer corresponding to the center portion of the half-tone phase shifter 204 can be set to 0.

[0129]Since light intensity distribution is proportional to the square of complex amplitude transmissivity, the light intensity on the wafer corresponding to the center portion of the half-tone phase shifter 204 is also set to 0. Therefore, as shown in drawing 23 (d), the high light intensity distribution of contrast can be acquired on a wafer.

[0130]Drawing 24 is a detail view of an example of a mask superposition mark. The inner periphery mark 2102 is formed in the transparent substrate 203, and the half-tone phase shifter 204 is formed on it. The peripheral part mark of the phase phi of arbitrary lights is formed in the outside. Thus, if the formed mask superposition mark is used, when exposing a transparent substrate with the polarization mask used two sheets, it is effective in the ability to shorten the make-ready time of mask superposition.

[0131]Compared with an exposure region, length l of drawing 25 of the long side of a recurrent pattern is an example in the case of being short. in this case, the peripheral part of the half-tone phase shifter 204 -- the time -- detailed -- the light-shielding film patterns 2051, 2052, and 2053 are arranged as shown in a figure. Then, the portion in which a light transmission section and the half-tone phase shifter 204 have a peripheral part of the half-tone phase shifter 204 serves as an optical shade part, and it becomes possible to expose the pattern of the high resolution which was excellent in pattern separation.

[0132]The example of the isolated pattern in which four corners are cuted off the corners, and drawing 26 (b) of drawing 26 (a) are the examples of the isolated pattern in which four corners have become circle-like.

[0133]Drawing 27 is an example of the projection aligner of this invention.

[0134]Drawing 27 (a) is a projection aligner of this invention, and 1 is the illumination light. Although the formation method of the illumination light is described in detail later, B_0 which is the partial light of this illumination light, B_{90}, B_{180}, and B_{270} have the linear polarization shown in a figure, respectively, and when there is no polarization mask 2, they irradiate with a zona-orbicularis-like belt top like the illumination light 11 on the pupil 3 of the reducing

glass 31 which is a projection optical system. this -- irradiation light -- B_{0} -- ' -- B_{90} -- ' -- B_{180} -- ' -- B_{270} -- ' -- this -- a pupil -- a top -- a figure -- being shown -- as -- linear polarization -- becoming -- **** .

[0135]On the polarization mask 2 of this invention, EB drawing of pattern I_1 which turned to the x direction and the y direction, for example, I_2, I_3, and the I_4 is carried out, it irradiates with these patterns and the polarization characteristic according to the direction which these patterns turn to is given to a transmitted light. Each example shown in drawing 1 thru/or drawing 22 is applicable to the polarization mask 2.

[0136]That is, since end C_1C_2 of the pattern has turned to the y direction as shown in drawing 28 if its attention is paid to I_2 shown in drawing 27 (b), the linear polarization of a y direction is penetrated about 100%, and the linear polarization of a x direction is shaded. The illumination light which has the directivity of B_{90} and B_{270} effectually will penetrate the portion similarly surrounded by $C_1C_2C_3C_4$, The light which spread in the wide range (range equivalent to a pupil diameter) on a pupil contributes to image formation, and it becomes possible for the pattern of high resolution to expose the diffracted light from this pattern to the exposure chip area 4 on the wafer 41.

[0137]The polarization component of a y direction penetrates this similarly to the pattern which turned to the pattern end face and the y direction of C_1C_2, and a x direction exposes the pattern of a y direction to high resolution by shading. Thus, the polarization characteristic of pattern dependence is given to the polarization mask 2, polarization is used well, and each pattern makes only the convenient directive illumination light for high resolution penetrate effectually, and realizes exposure of high resolution.

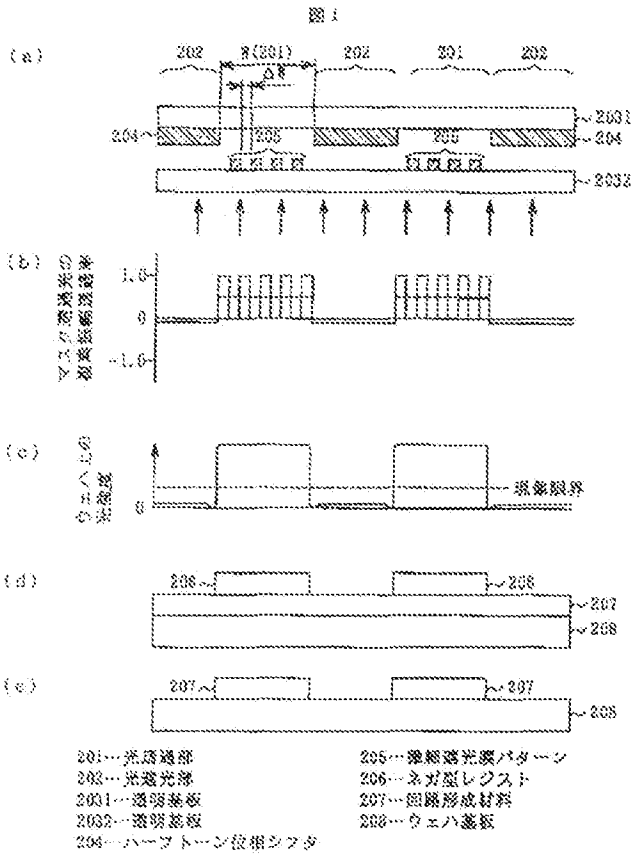
[0138]Drawing 28 is the figure to which I_2 pattern of drawing 27 (b) was expanded. It is L shape isolated pattern, and the detailed light-shielding film patterns 2051 and 2052 are carrying out L shape, and the half-tone phase shifter 204 has surrounded the periphery.

[0139]

[Effect of the Invention]By using the polarization mask of this invention, the exposure method using it, and the projection aligner using it, Exposure of the pattern which was far excellent in resolution compared with the conventional resolving pattern using the projection optical system of the exposure device used conventionally as it is is attained, The large economic effect by the large improvement in the integrated circuit art by the improved efficiency of an integrated circuit, the improvement in a production yield of an integrated circuit, and reduction of integrated circuit manufacturing facility investment can be planned.

[Translation done.]

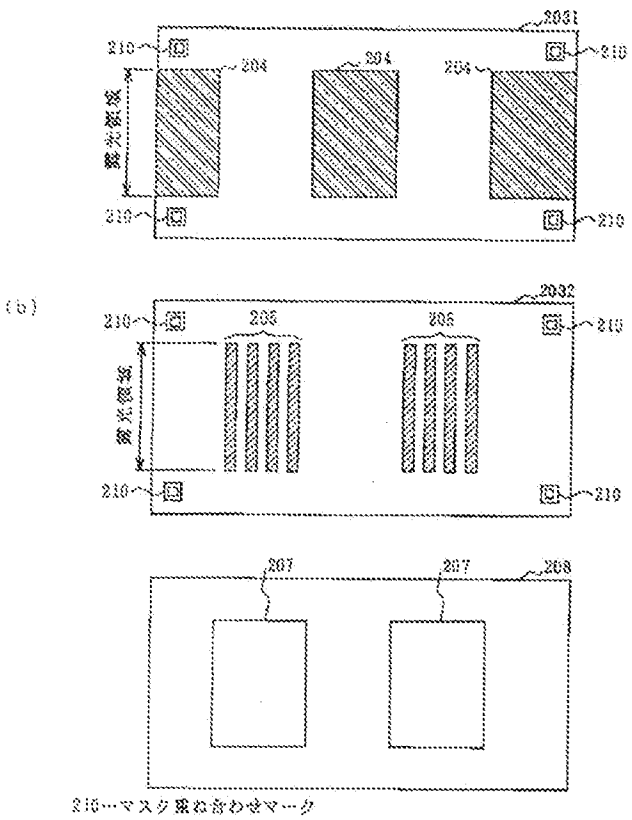
Drawing selection Drawing 1



[Translation done.]

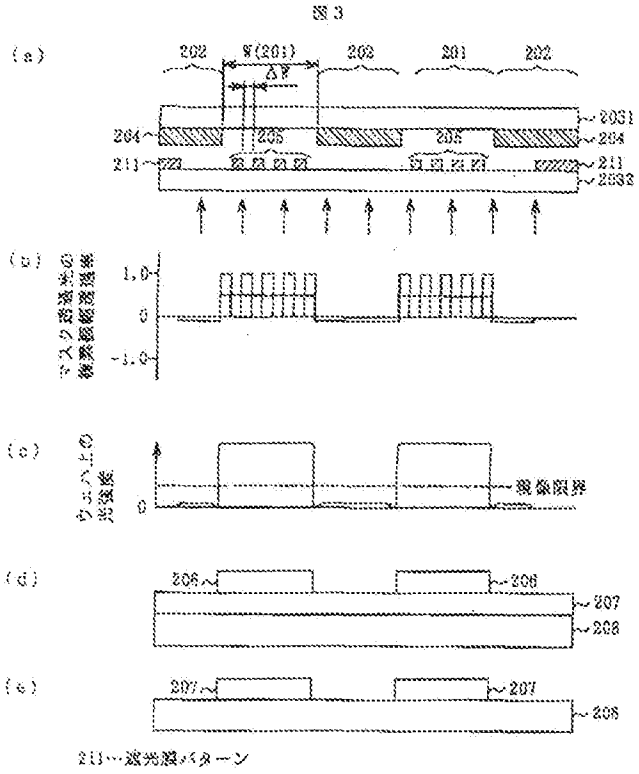
Drawing selection Drawing 2

図２



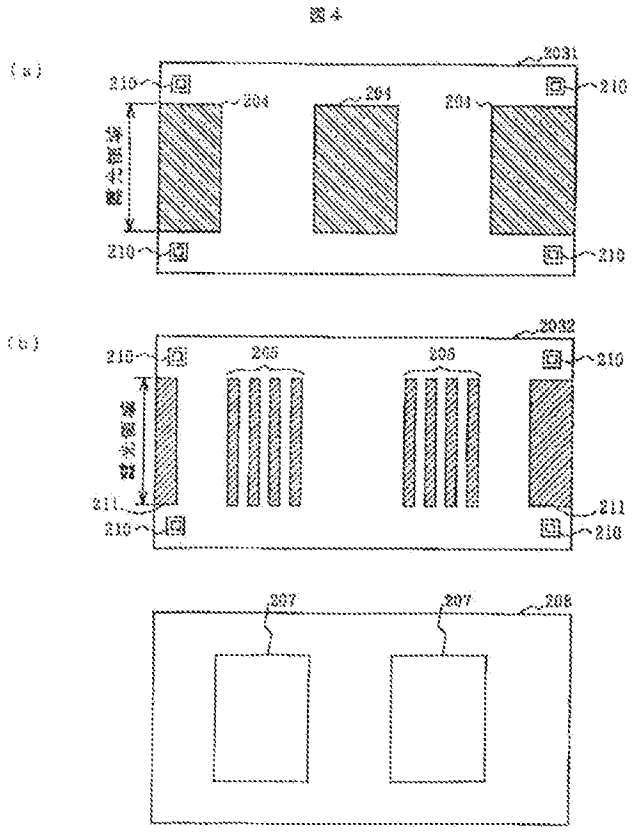
[Translation done.]

Drawing selection Drawing 3



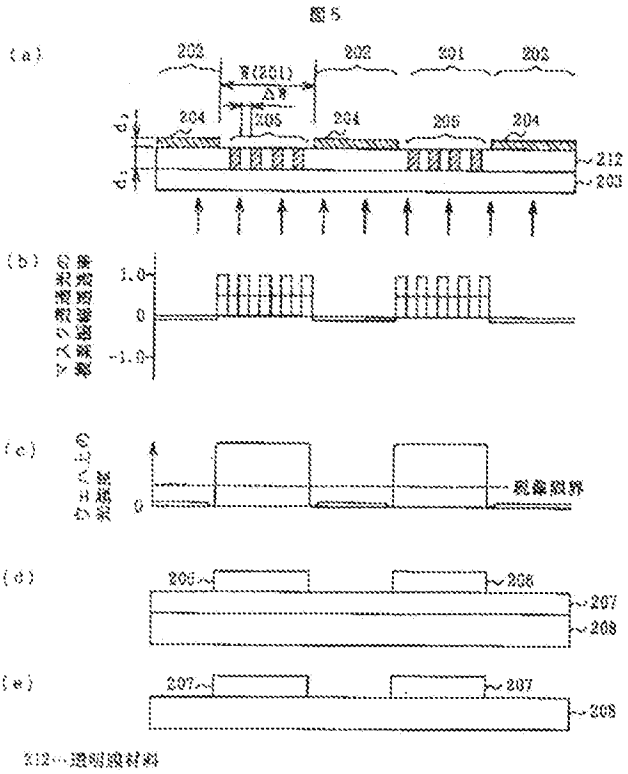
[Translation done.]

Drawing selection Drawing 4



[Translation done.]

Drawing selection Drawing 5

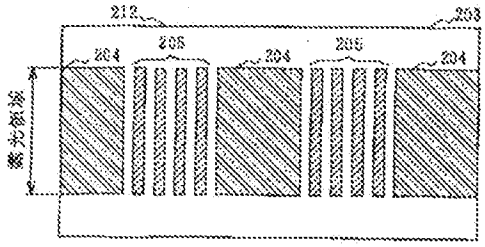


[Translation done.]

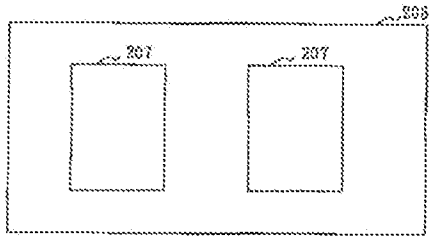
Drawing selection Drawing 6

図 6

(a)

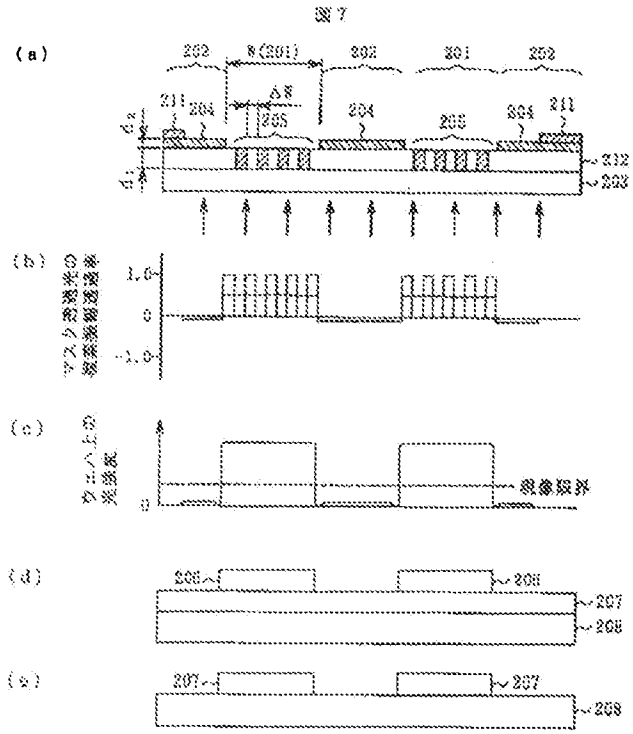


(b)



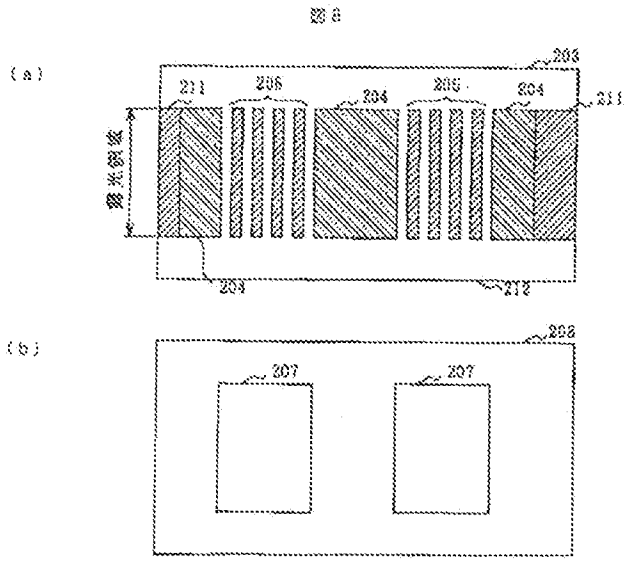
[Translation done.]

Drawing selection Drawing 7



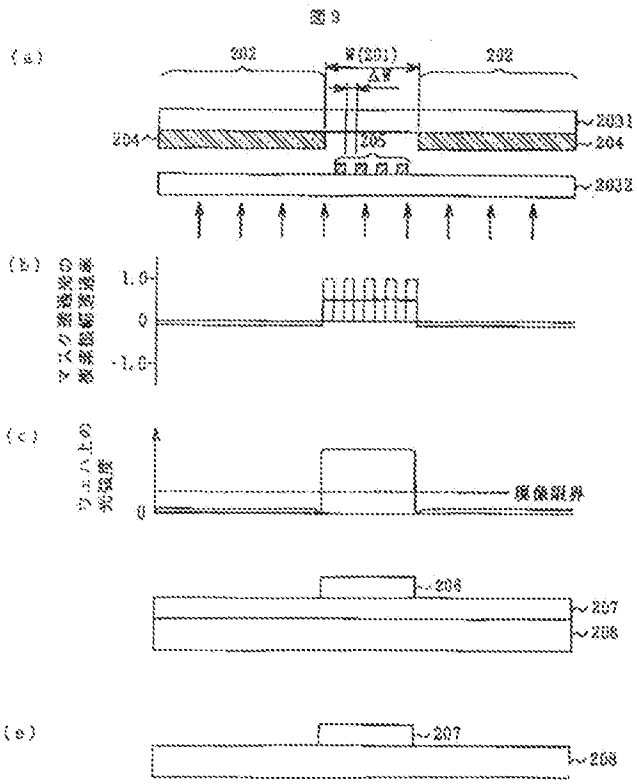
[Translation done.]

Drawing selection Drawing 8



[Translation done.]

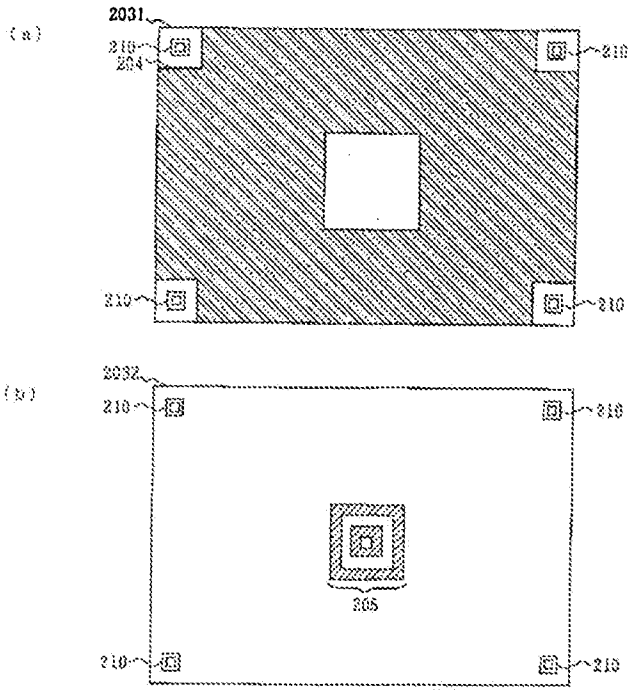
Drawing selection Drawing 9



[Translation done.]

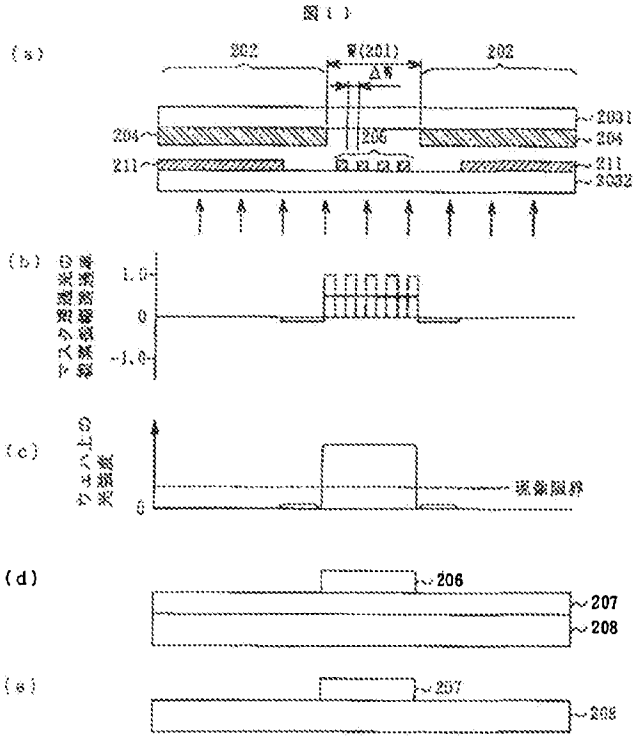
Drawing selection Drawing 10

図10



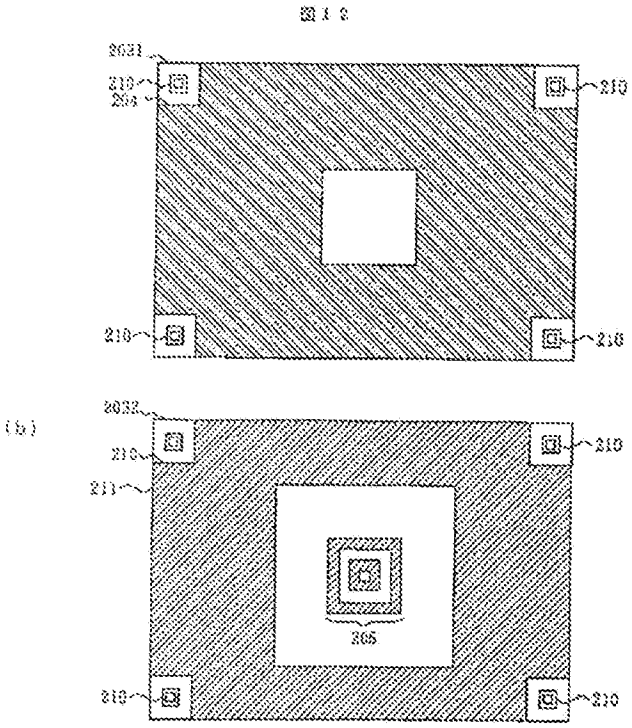
[Translation done.]

Drawing selection Drawing 11



[Translation done.]

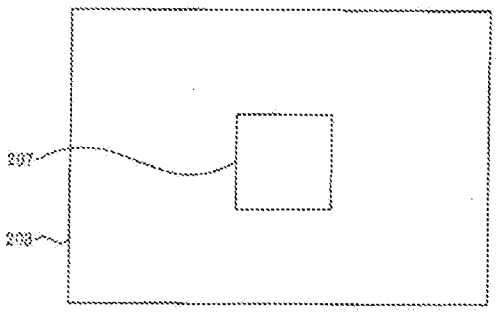
Drawing selection Drawing 12



[Translation done.]

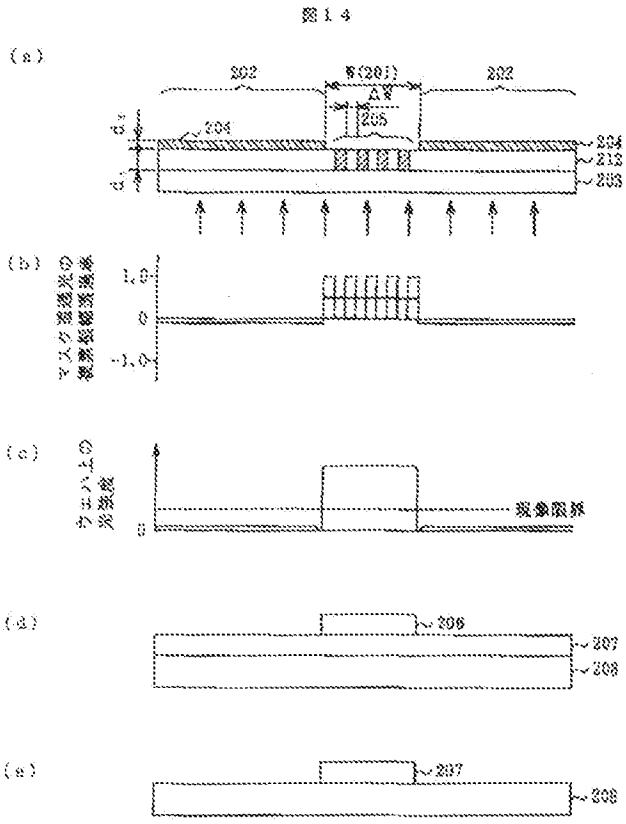
Drawing selection Drawing 13

図１３



[Translation done.]

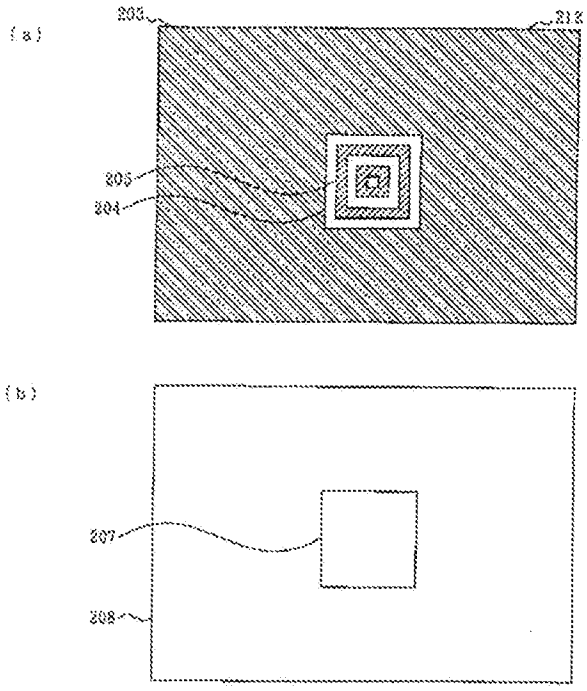
Drawing selection Drawing 14



[Translation done.]

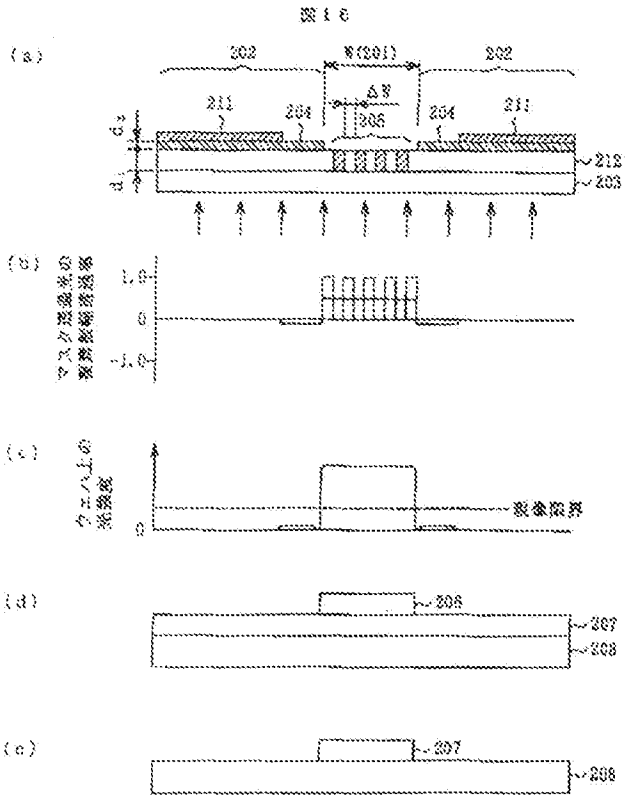
Drawing selection Drawing 15

図15



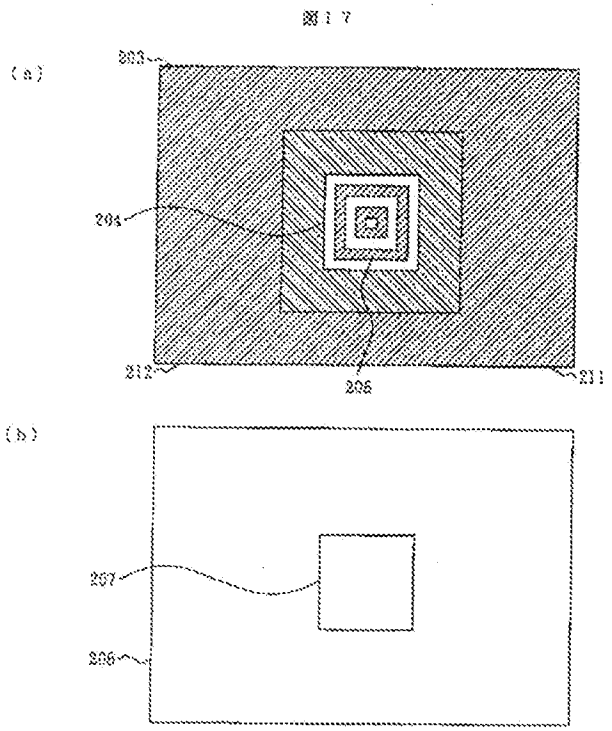
[Translation done.]

Drawing selection Drawing 16



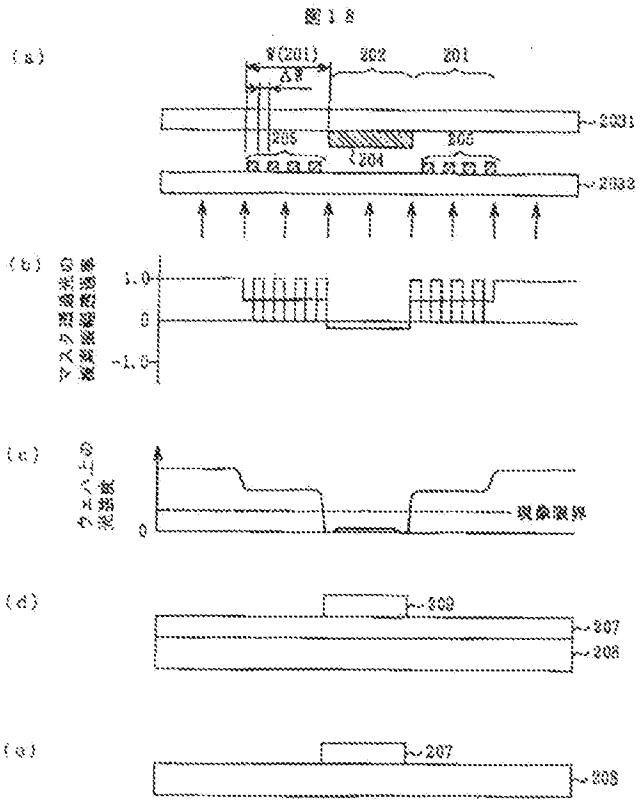
[Translation done.]

Drawing selection Drawing 17



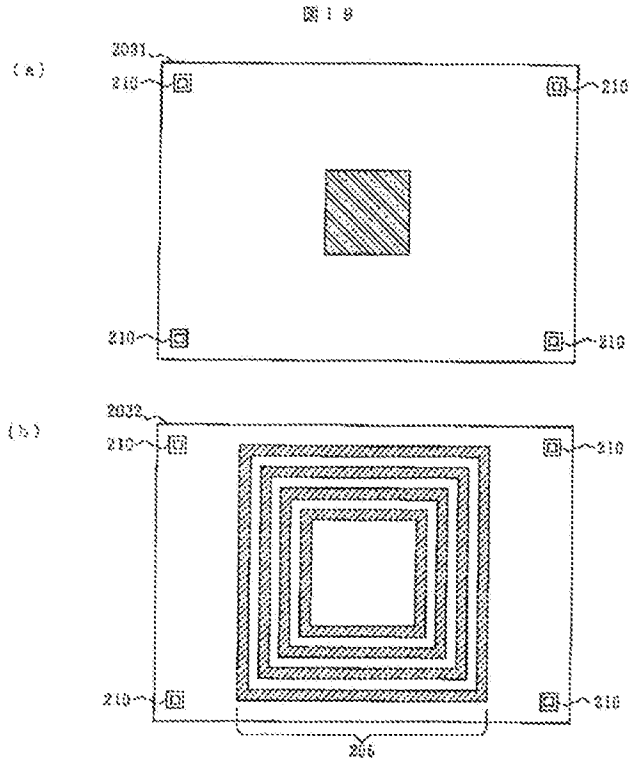
[Translation done.]

Drawing selection Drawing 18



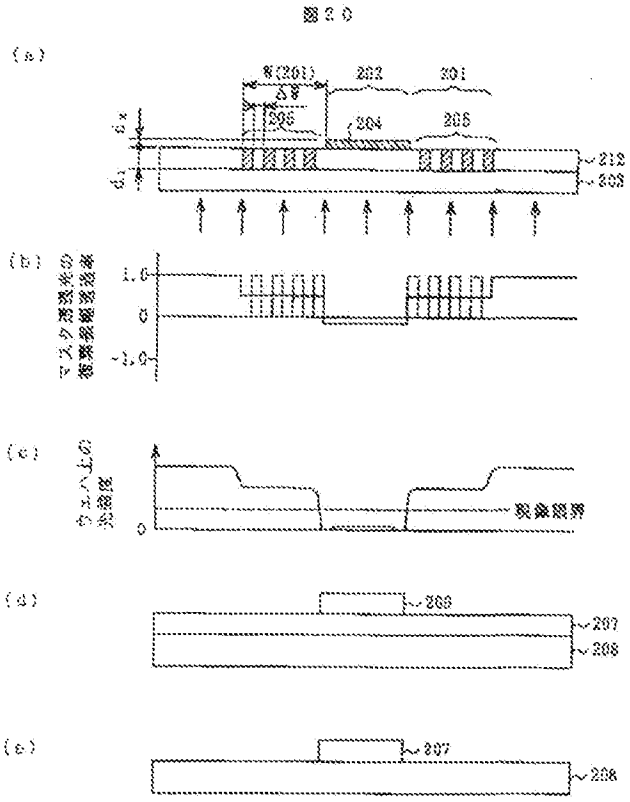
[Translation done.]

Drawing selection Drawing 19



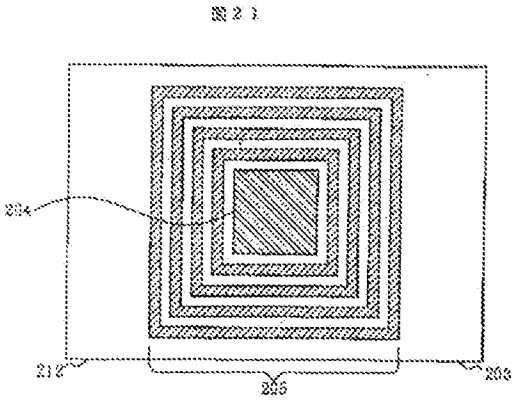
[Translation done.]

Drawing selection Drawing 20



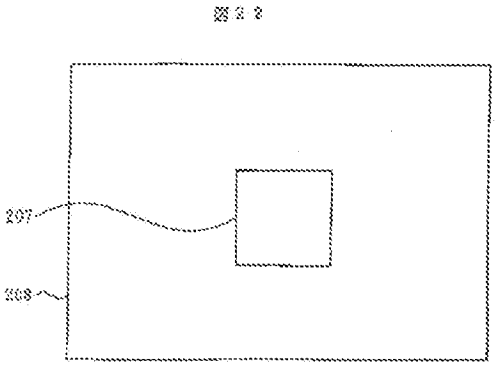
[Translation done.]

Drawing selection Drawing 21



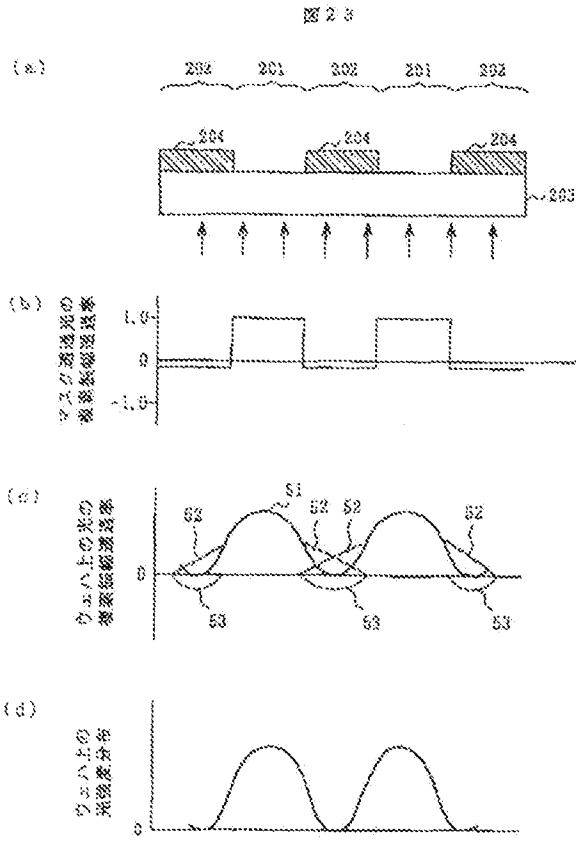
[Translation done.]

Drawing selection Drawing 22



[Translation done.]

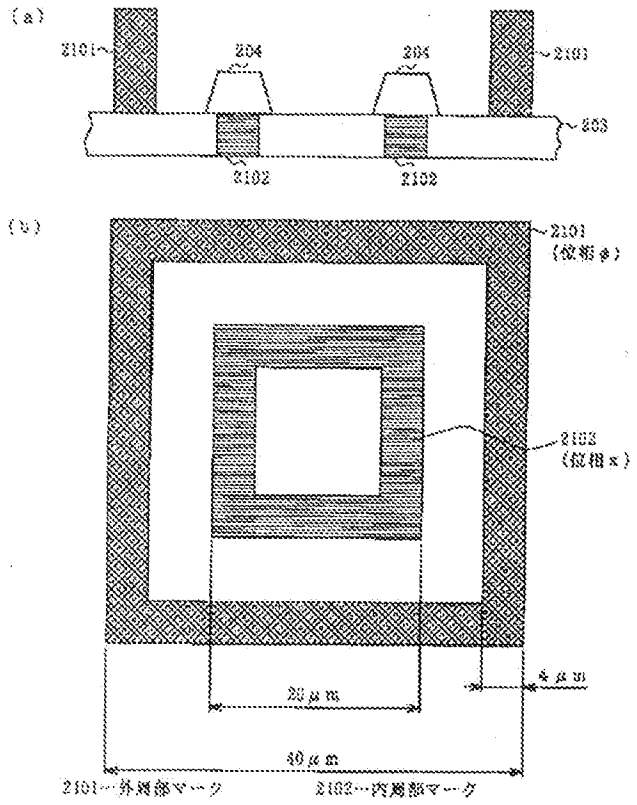
Drawing selection Drawing 23



[Translation done.]

Drawing selection Drawing 24

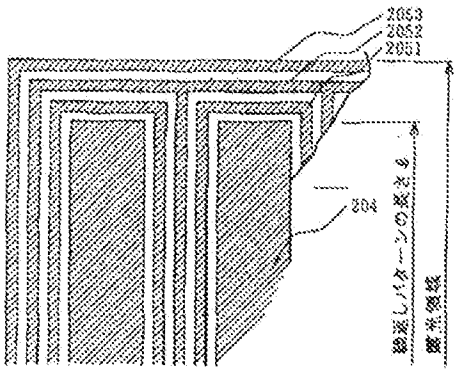
図２４



[Translation done.]

Drawing selection Drawing 25

図２５



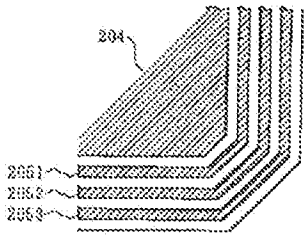
204…ハーフトーン位相シフタ
2051…最終遮光膜パターン
2052…最終遮光膜パターン
2053…最終遮光膜パターン

[Translation done.]

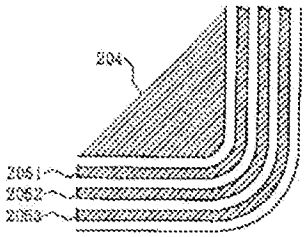
Drawing selection Drawing 26

図２６

(a)



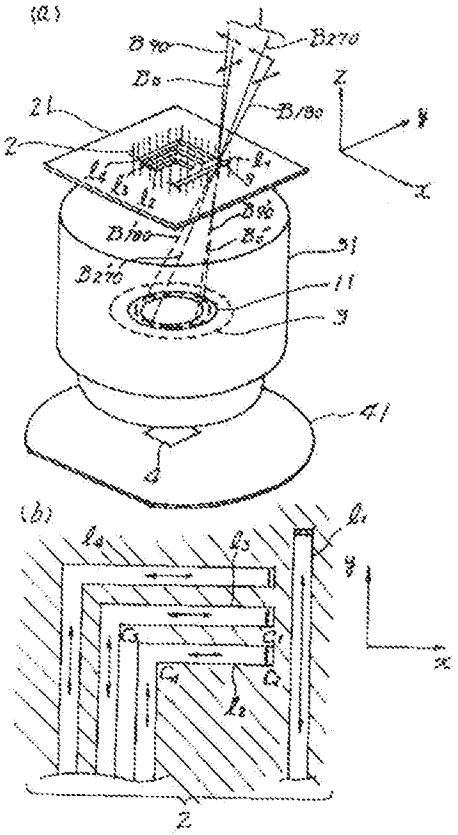
(b)



[Translation done.]

Drawing selection Drawing 27

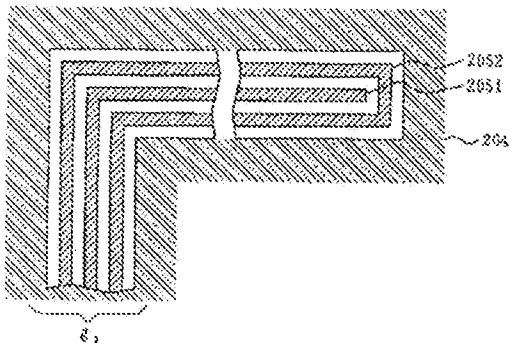
図 27



[Translation done.]

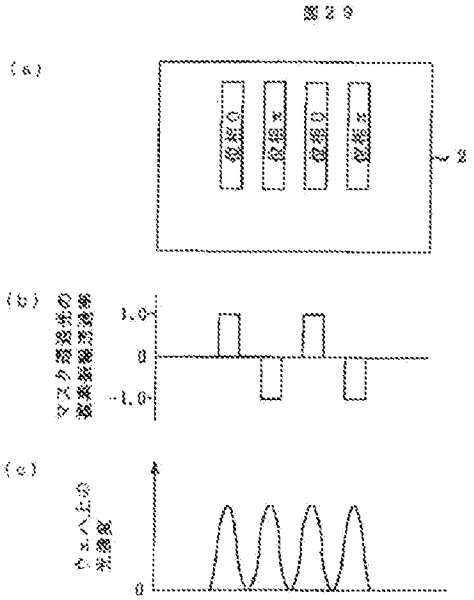
Drawing selection Drawing 28

図２８



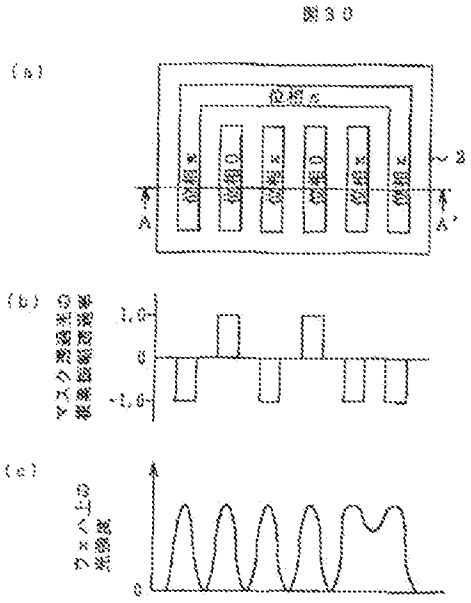
[Translation done.]

Drawing selection Drawing 29



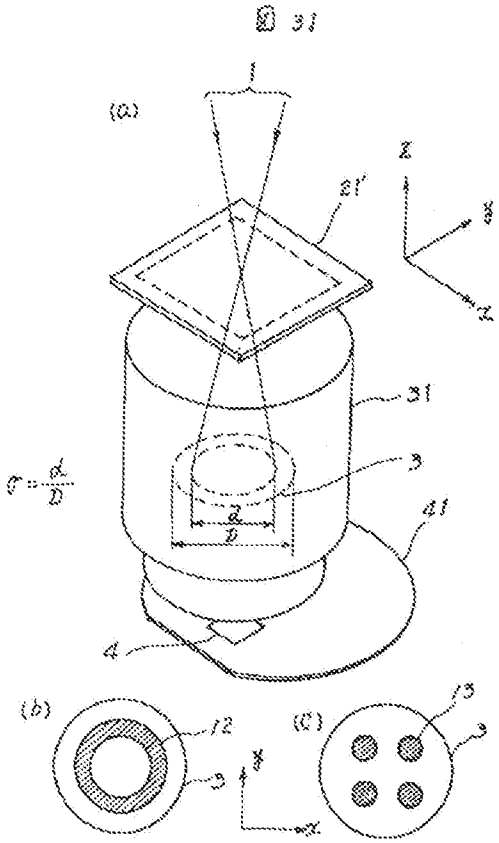
[Translation done.]

Drawing selection Drawing 30



[Translation done.]

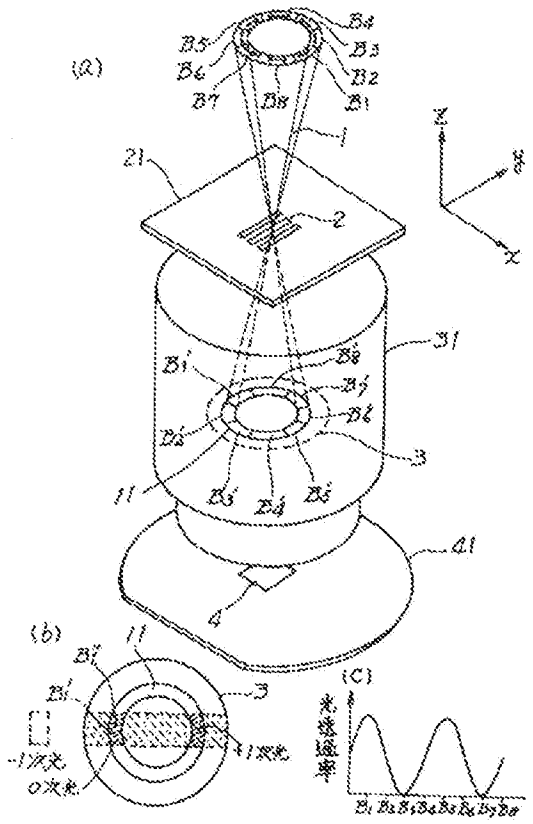
Drawing selection Drawing 31



[Translation done.]

Drawing selection Drawing 32

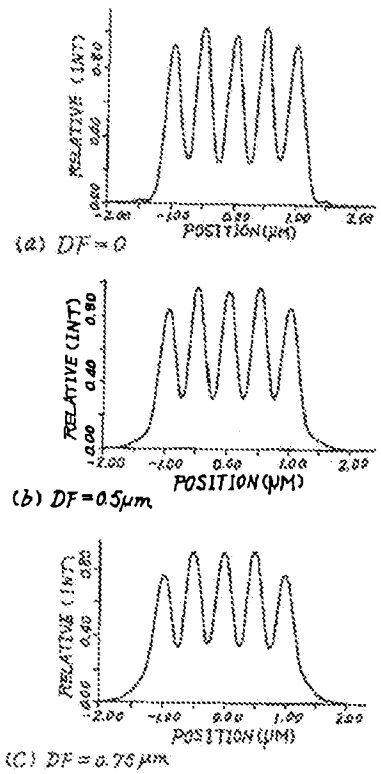
図 32



[Translation done.]

Drawing selection Drawing 33

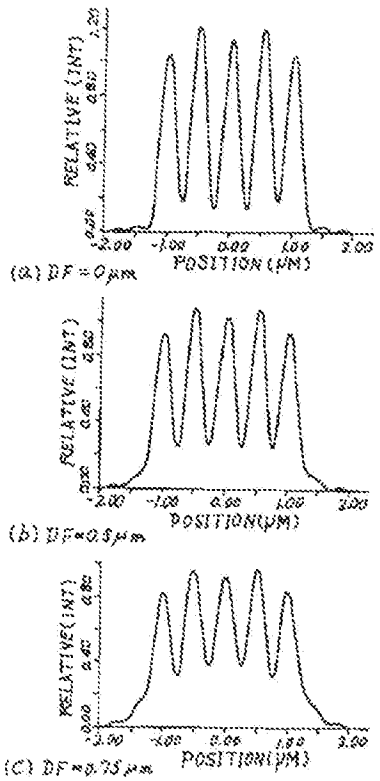
図 33



[Translation done.]

Drawing selection Drawing 34

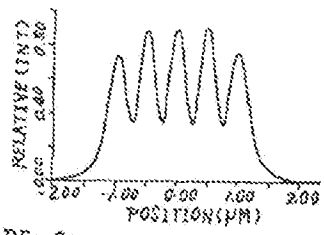
図 34



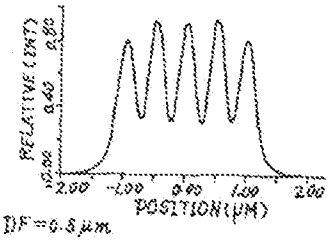
[Translation done.]

Drawing selection Drawing 35

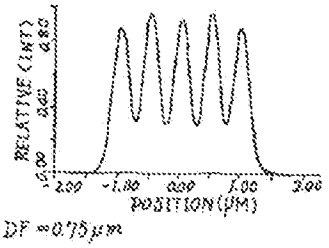
図 35



(a) DF=0μm



(b) DF=0.5μm

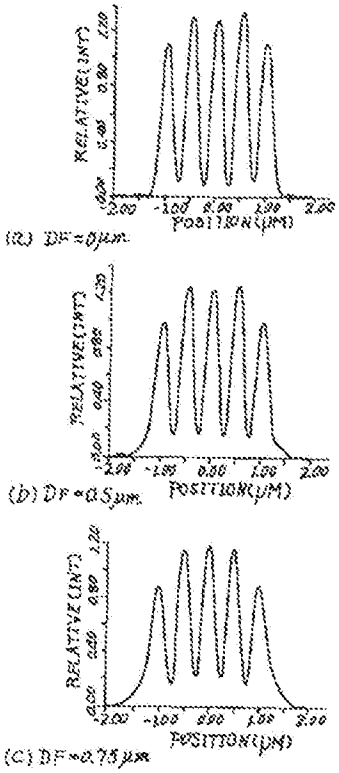


(c) DF=0.75μm

[Translation done.]

Drawing selection Drawing 36

図 36



[Translation done.]